CPUE Estimates and Catch-age Analysis of Burbot in the Tanana River Drainage, 1994

by

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Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used in Division of Sport Fish Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications without definition. All others must be defined in the text at first mention, as well as in the titles or footnotes of tables and in figures or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd

Spell out acre and ton.

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s

Spell out year, month, and week.

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H_0
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

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ABSTRACT

As part of an ongoing stock assessment program, burbot were sampled in two river sections (approximately 25 km), one each in the Tanana and Chena rivers, representing the area where most fishing harvest occurs. These sections have been sampled annually since 1986 and 1988, respectively. A systematic sampling design was used, whereby hoop traps were set and moved daily. Estimates of mean catch per unit effort, mean length, length distributions, and proportions of catch for three size categories were calculated. Estimates for each were within the range of observed values from previous sampling years. Seasonal variations in catch rate and composition was cited as a problem in interpreting these annual estimates. Due to the difficulty in interpreting estimates of mean catch per unit effort, an alternative stock assessment method was investigated. Catch-age analysis was used to combine harvest estimates from the statewide harvest survey and age composition from catch sampling with auxiliary information in the form of angler effort to estimate exploitable abundance of burbot in the Tanana River drainage. The CAGEAN model results showed a decreasing trend in exploitable abundance from 1987 to 1993. Catch-age analysis appears to be a promising method for estimating abundance of burbot in the Tanana River drainage.

Key words: burbot, *Lota lota*, hoop traps, Tanana River, Chena River, catch per unit effort, mean length, catch-age analysis, CAGEAN, exploitable abundance.

CHAPTER 1. CPUE ESTIMATES OF BURBOT IN THE CHENA AND TANANA RIVERS, 1994

INTRODUCTION

Research concerning burbot *Lota lota* stocks in flowing waters of the Tanana River system has been ongoing since 1983. The objectives of this research program have been to determine biological characteristics such as size, age, and density distributions, identify migratory and reproductive behavior, examine spawning characteristics, monitor harvests, and determine characteristics of the sport fishery. Results of this research have been published in a number of documents (Hallberg 1984 - 1986; Hallberg et al. 1987; Guinn and Hallberg 1990; Evenson 1988, 1989, 1990a, 1990b, 1991, 1992, 1993a, 1993b, 1994; Evenson and Hansen 1991; Clark et al. 1991; Bernard et al. 1991).

Initially, this research sought to identify individual stocks by identifying movements throughout the system. This was accomplished through a rigorous sampling program which marked and subsequently recaptured burbot in the mainstream Tanana River and in many tributary streams. More recently (Evenson 1993b), radio telemetry was used to monitor seasonal movements and identify spawning concentrations in attempt to refine stock definitions. This information indicated that movements were frequent and extensive throughout the system, and that for management purposes, the entire drainage should be considered a single stock (Evenson 1989 and 1990b).

Assessment of this stock has been accomplished by estimating abundance, relative abundance through mean catch per unit effort (CPUE), and length compositions for many river sections throughout the system using a standardized design. These estimates have been obtained annually or semi-annually for important river sections (areas of large harvest such as the Chena and Tanana rivers near the city of Fairbanks) This assessment has indicated that annual exploitation is low relative to abundance for the entire system. Thus, the stock assessment research has been reduced, and is focused toward those river sections where a substantial harvest occurs.

Since 1986, when extensive stock assessment sampling began, a number of estimates of abundance, CPUE, and mean length have been obtained. Estimates from 1986 through 1992 are summarized by Evenson (1993a); estimates for 1993 are presented by Evenson (1994). The purpose of this investigation was to continue stock monitoring in the Tanana and Chena rivers near Fairbanks. The specific objectives was to estimate mean CPUE for all burbot 450 mm total length (TL) and longer

one 24 km section of the Tanana River and in one 27 km section of the Chena River. In addition, other statistics regarding length compositions are presented and compared to previous years data.

STUDY AREA

The Tanana River is of glacial origin flowing over 900 km and draining 115,255 square kilometers. The study area in this investigation included a 24 km section of the Tanana River extending downstream from the confluence of the Chena River, and a 27 km section of the Chena River extending upstream from it's confluence with the Tanana River (Figure 1). These same two sections have been sampled annually since 1986 and 1988, respectively, using a similar sampling design.

METHODS

Gear Description

Burbot were captured in commercially available hoop traps. Two sizes of traps have been during the past eight years. The larger of the two traps were used during all years prior to 1988, while the smaller traps were used in all following years. Bernard et al. (1991) provides a comprehensive account of the efficacy of both large and small traps. In general, both sizes are effective at catching burbot greater than 300 mm total length (TL), however burbot do not fully recruit to either gear until 450 mm TL. For all lengths 800 mm and larger, large traps are more effective than small traps. Small hoop traps were chosen as a sampling gear beginning in 1988 because they are more easily transported, and more traps can be deployed during a sampling day.

Small hoop traps were 3.05 m long with seven 6.35 mm steel hoops (Figure 2). Hoop diameters tapered from 0.61 m at the entrance to 0.46 m at the cod end. Each trap had a double throat (tied to the second and fourth hoops) which narrows to an opening 10 cm in diameter. All netting was knotted nylon woven into 25 mm bar mesh, bound with No, 15 cotton twine, and treated with an asphaltic compound. Each trap was kept stretched with two sections of 19 mm polyvinyl chloride (PVC) pipe attached by snap clips to the end hoops.

Large hoop traps were of similar design, but were 3.66 m long, and had fiberglass hoops with inside diameters tapering from 91 to 69 cm (Figure 2). Throat diameters were 36 cm. Spreader bars made from PVC were also used to keep the traps stretched.

Hoop traps were baited with cut Pacific herring *Clupea harengus* placed in perforated plastic containers. One end of a five to 10 m section of polypropylene rope was tied to the cod end of each trap, while the other end was tied off to shore. The traps then fished on the river bottom near shore with the opening facing downstream. An outboard-powered riverboat was used to set, move, and retrieve the traps.

Study Design

The sampling design used this year was modified slightly from the design used in previous years. In past years, sampling was conducted by two crews for a period of one week (five days and four nights), while this years sampling was conducted by one crew over a period of two weeks. A systematic sampling design was used in which traps were set along both shores at near equal intervals beginning at the most downstream end of the section and progressing to the most upstream end of the section. In previous years, traps were set at a density of three traps per kilometer per day, while during 1994 traps were set at half this density. Catch per unit effort can be quite variable over short periods of time (Evenson 1994). It was believed that extending the sampling period from one week with two crews to two weeks with one crew would provide an estimate of mean CPUE which would be more comparable across years without increasing sampling cost. All traps were fished for approximately 24 h, were rebaited, and were moved to a slightly upstream area. All trap locations were marked on a 1:63,360

2

Chena Section

Little Chena River

Chena River

Fairbanks

Rosie Cr

Tanana River

Moose Cr.

Salchaket Slough

Bonanaza Cr

Sam Charley I.

Eielson

AFB

Tanana Section

Whiskey I.

Willow Creek

Crooked Creek

N

Wood River

0   10 km

3
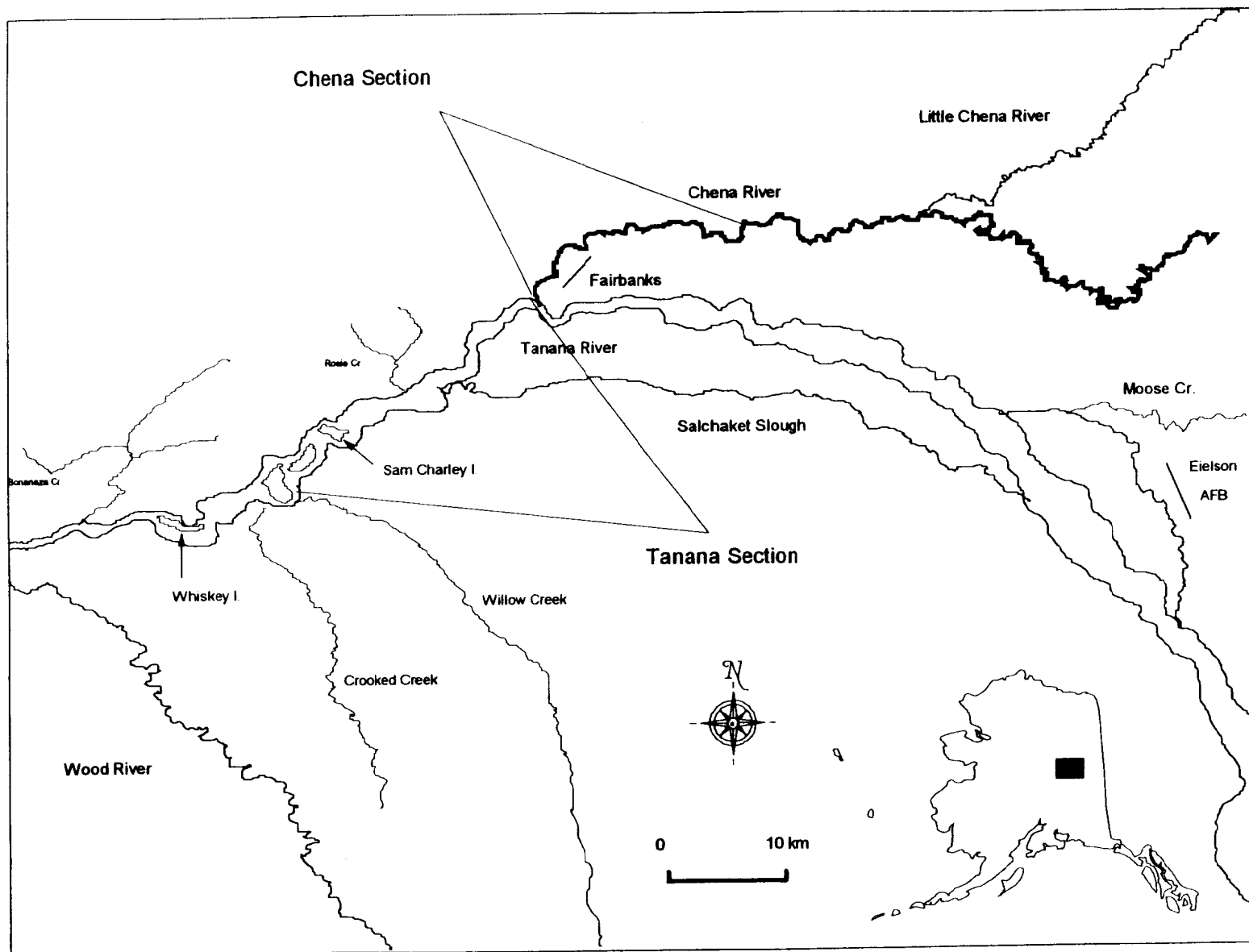
Figure 1.-Map showing sections of the Tanana and Chena rivers sampled during 1994.
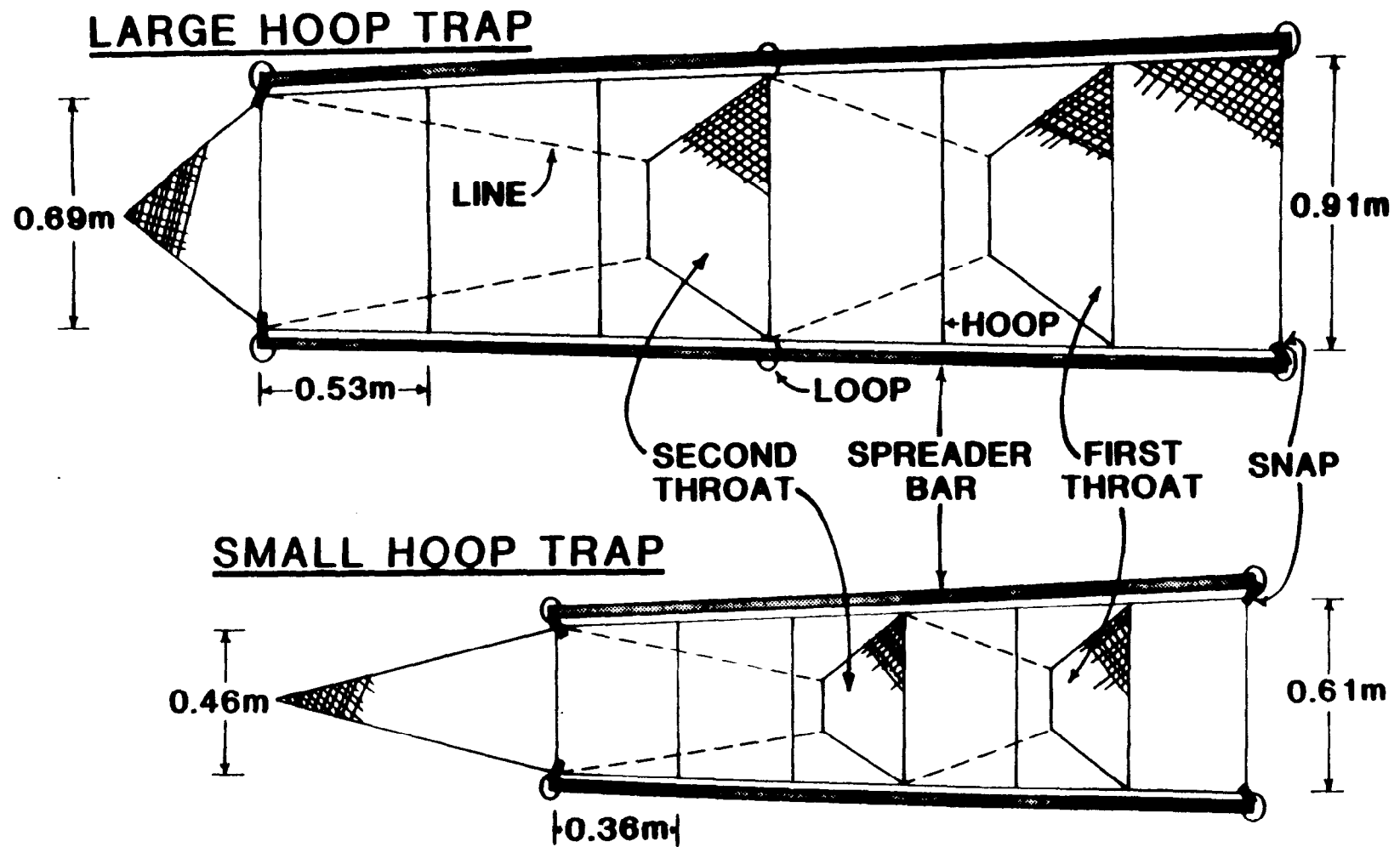
Figure 2.-Diagrams of large and small hoop traps used to catch burbot in flowing waters of the Tanana River drainage.

USGS maps and were recorded to the nearest kilometer. All burbot captured were measured for total length (TL) to the nearest millimeter, and were tagged using individually numbered Floy internal anchor tags. All fish were released at the capture sight.

Data Analysis

Due to the size selectivity of hoop traps described above, estimates of mean CPUE and length composition statistics described below are given for three length strata: "small" ($\leq$450 mm TL) "medium" (450-799 mm TL) and "large" ($\geq$800 mm TL).

Catch per Unit Effort

Mean CPUE for each river section and its associated variance were calculated from the number of burbot caught per net-night for all traps set during each sampling period based upon the following equations from Wolter (1984):

$$\overline{CPUE_c} = \overline{X_c} = \frac{\sum_{h=1}^{t} X_{ch}}{t} \tag{1}$$

$$V\left[\overline{CPUE_c}\right] = \frac{\sum_{h=2}^{t} (X_{ch} - X_{ch-1})^2}{2t(t-1)} \tag{2}$$

where:

X_{ch} = catch of burbot of size class c in hoop trap h (where h=1 to t where h=1 the most downstream set and h=t the most upstream); and,

t = the total number of hoop traps in a river section.

All estimates of mean CPUE are given in units of number of burbot per net per overnight set, or burbot per net-night (bb/nn).

Length Composition

Length compositions of burbot sampled in these two sections were examined using three methods. Mean lengths and proportions of total catch for each of the three size categories were calculated. In addition, length distributions for various sampling years were plotted and compared.

Mean length and its associated variance was also calculated for three length categories as:

$$\overline{l_a} = \sum_{b=1}^{n} \frac{l_{ab}}{n_a} \tag{3}$$

$$V\left[\overline{l_a}\right] = \sum_{b=1}^{n} \frac{\left(l_{ab} - \overline{l_a}\right)^2}{n_a(n_a - 1)} \tag{4}$$

where:

5

l_{ab} = length of burbot b in category a; and,

n_a = number of samples in length category a.

All estimates of mean length are expressed to the nearest 1mm TL.

Proportions of total catch for each length category and associated variances were calculated as:

$$\hat{P}_z = \frac{n_z}{n} \tag{5}$$

$$V[\hat{P}_g] = \frac{\hat{P}_z(1 - \hat{P}_z)}{n - 1} \tag{6}$$

$\hat{P}_z$ = the estimated proportion of burbot in category z;

n_z = number of samples in length category z; and,

n = the total number of burbot in the sample.

RESULTS

In the Tanana River during 1994, 344 burbot were caught and 331 were measured for length with 317 net-nights of effort. Estimates of mean CPUE were 0.50 bb/nn (SE = 0.05) for small burbot, 0.55 bb/nn (SE = 0.05) for medium burbot, and 0.01 bb/nn (SE = 0.01) for large burbot. In the Chena River, 179 burbot were caught and 178 were measured for length with 200 net-nights of effort. Estimates of mean CPUE were 0.19 bb/nn (SE = 0.01) for small burbot, 0.65 bb/nn (SE = 0.08) for medium burbot, and 0.02 (SE = 0.01) for large burbot.

A summary of annual CPUE estimates for these two sections is shown in Table 1. In general, the CPUE estimates from 1994 in the Tanana River section are within the range of estimates from previous years. In the Tanana River, the mean CPUE estimate for small burbot was slightly higher than the previous four years, while the estimate for medium burbot was slightly lower than the previous four years. Mean CPUE estimates for large burbot are typically low compared to those of medium and small burbot, however the 1994 estimate was at the lower end of observed values. Mean CPUE estimates from 1994 in the Chena River were also within the observed range of estimates from previous years for all size categories, but were all higher than the previous two years estimates.

Estimates of mean length for burbot sampled from the Tanana River section were 382 mm TL (SE = 4) for small burbot, 529 mm TL (SE = 6) for medium burbot, and 864 mm TL (SE = 23) for large burbot. Estimates of mean length for burbot sampled from the Chena River section were 395 mm TL (SE = 7) for small burbot, 573 mm TL (SE = 6) for medium burbot, and 839 (SE = 28) for large burbot. A summary of annual mean length estimates for these two sections is shown in Table 2. Mean lengths for burbot in all three size categories in 1994 were within the range of estimates from previous years.

Due to size selectivity of the hoop traps, proportions of total catch attributed to each of the three size categories do not represent true population proportions, but do provide a means of comparison. Large

Table 1.-Catch per unit effort (CPUE) estimates of burbot sampled in sections of the Tanana and Chena rivers, 1986-1994

River Sampling Dates	Year	km Sampled	Trap Size	Net Nights	Small (300-449 mm TL) Catch	CPUE	SE	Medium (450-799 mm TL) Catch	CPUE	SE	Large (≥800 mm TL) Catch	CPUE	SE	Medium + Large (≥450 mm TL) Catch	CPUE	SE
Tanana River																
07/29-08/02	1986[a]	334-352	Large	99	51	0.52	NA	94	0.95	NA	7	0.07	NA	101	1.02	NA
08/11-08/15	1986[a]	334-352	Large	128	42	0.33	NA	57	0.45	NA	3	0.02	NA	60	0.47	NA
07/22-07/25	1987[a]	339-354	Large	77	22	0.29	0.02	41	0.53	NA	6	0.08	NA	47	0.61	0.09
07/28-07/31	1987[a]	339-354	Large	106	70	0.66	0.10	73	0.69	NA	6	0.06	NA	79	0.75	0.09
08/04-08/07	1987[a]	339-354	Large	79	24	0.30	0.08	45	0.57	NA	2	0.03	NA	47	0.59	0.10
08/18-08/21	1987[a]	339-354	Large	183	46	0.25	0.05	178	0.97	NA	14	0.08	NA	192	1.05	0.11
07/06-07/09	1988	312-376	Small	268	159	0.59	0.05	144	0.54	NA	1	<0.01	NA	145	0.54	0.05
06/13-06/16	1989	317-374	Small	237	137	0.58	0.06	125	0.53	NA	6	0.03	NA	131	0.55	0.05
08/14-08/16	1990	344-376	Small	90	44	0.49	0.10	96	1.07	NA	4	0.04	NA	100	1.11	0.12
07/11-07/17	1991	336-360	Small	310	97	0.31	0.04	247	0.80	0.07	3	0.01	0.01	250	0.81	0.07
08/24-08/28	1992	336-360	Small	277	57	0.21	0.03	266	0.96	0.08	16	0.06	0.01	282	1.02	0.08
06/08-06/11	1993	336-360	Small	257	85	0.32	0.04	175	0.67	0.05	6	0.02	<0.01	181	0.70	0.05
06/07-06/17	1994	336-360	Small	317	157	0.50	0.05	173	0.55	0.05	4	0.01	0.01	177	0.56	0.05
Chena River																
09/07-09/09	1988	0-24	Small	88	23	0.32	0.08	65	0.90	0.13	0	0	0	65	0.90	0.13
06/12-06/15	1990[a]	0-24	Small	232	14	0.06	0.02	16	0.07	NA	0	0	0	16	0.07	0.02
08/21-08/24	1990[a]	0-24	Small	204	41	0.20	0.04	82	0.40	NA	1	<0.01	NA	83	0.41	0.06
08/27-08/31	1990[a]	0-24	Small	203	59	0.29	0.04	204	1.00	NA	1	<0.01	NA	205	1.01	0.11
09/06-09/07	1990[a]	0-24	Small	73	26	0.36	0.03	90	1.23	NA	0	0	0	90	1.23	0.09
09/27-09/28	1990[a]	0-24	Small	80	9	0.11	0.03	66	0.83	NA	2	0.03	NA	68	0.85	0.05
08/27-08/30	1991[a]	0-24	Small	268	35	0.13	0.03	218	0.81	0.09	0	0	0	218	0.81	0.09
09/04-09/07	1991[a]	0-24	Small	248	28	0.11	0.03	171	0.69	0.08	3	0.01	<0.01	174	0.70	0.08
08/31-09/04	1992	0-24	Small	272	19	0.07	0.02	111	0.41	0.05	1	<0.01	<0.01	112	0.41	0.05
08/17-08/20	1993	0-24	Small	257	23	0.08	0.01	127	0.49	0.09	0	0	0	127	0.49	0.09
08/31-09/09	1994	0-27	Small	200	38	0.19	0.03	137	0.69	0.08	4	0.02	0.01	141	0.71	0.08

[a] Data used as part of a mark-recapture experiment to estimate abundance.

[b] Data are not available for this estimate.

Table 2.-Mean length estimates of burbot sampled in sections of the Tanana and Chena rivers, 1986-1994.

River Sampling Dates	Year	River km Sampled	Hoop Trap Size	Length Range (mm TL)	Small (300-449 mm TL)			Medium (450-799 mm TL)			Large (≥800 mm TL)			Medium + Large (≥450 mm TL)		
					Catch	Mean	SE	Catch	Mean	SE	Catch	Mean	SE	Catch	Mean	SE
Tanana River																
07/29-08/02	1986	334-352	Large	260-863	51	382	6	94	552	8	7	839	9	101	572	10
08/11-08/15	1986	334-352	Large	266-905	42	379	7	57	556	14	3	846	29	60	570	13
07/22-07/25	1987	339-354	Large	315-1,025	22	400	7	41	544	12	6	888	41	47	588	21
07/28-07/31	1987	339-354	Large	304-1,079	70	396	5	73	552	9	6	885	45	79	578	13
08/04-08/07	1987	339-354	Large	308-1,028	24	399	7	45	569	12	2	937	92	47	584	16
08/18-08/21	1987	339-354	Large	311-1,000	46	411	4	178	570	7	14	882	17	192	593	9
07/06-07/09	1988	312-376	Small	235-855	159	388	3	144	520	5	1	855	ID a	145	523	5
06/13-06/16	1989	317-374	Small	278-895	137	381	4	125	535	6	6	849	13	131	549	8
08/14-08/16	1990	344-376	Small	300-900	44	393	6	96	540	8	4	856	23	100	553	8
07/11-07/17	1991	336-360	Small	238-922	97	386	5	247	530	4	3	893	19	250	534	4
08/24-08/28	1992	336-360	Small	277-1,040	57	398	6	266	557	5	16	864	16	282	574	6
06/08-06/11	1993	336-360	Small	280-902	86	375	5	174	552	6	6	841	14	180	562	7
06/07-06/17	1994	336-360	Small	265-915	158	382	4	169	529	6	4	864	23	173	537	7
Chena River																
09/07-09/09	1988	0-24	Small	306-754	23	394	8	65	557	8	0	ID	ID	65	557	8
06/27-06/30	1989	0-40	Small	295-802	30	366	6	74	568	10	1	802	ID	75	571	10
06/12-06/15	1990	0-24	Small	265-600	14	375	14	16	510	12	0	ID	ID	16	510	12
08/21-08/24	1990	0-24	Small	302-873	41	400	7	82	540	8	1	873	ID	83	544	8
08/27-08/31	1990	0-24	Small	294-852	59	409	5	204	555	5	1	852	ID	205	556	5
09/06-09/07	1990	0-24	Small	316-762	26	391	9	90	554	7	0	ID	ID	90	554	7
09/27-09/28	1990	0-24	Small	315-905	9	381	18	66	554	9	2	888	18	68	564	9
08/27-08/30	1991	0-24	Small	288-785	35	385	8	218	562	5	0	ID	ID	218	562	5
09/04-09/07	1991	0-24	Small	295-895	28	382	9	171	565	5	3	850	27	174	569	5
08/31-09/04	1992	0-24	Small	307-843	19	388	10	111	575	7	1	843	ID	112	577	7
08/17-08/20	1993	0-24	Small	295-760	23	371	11	126	565	7	0	ID	ID	126	565	7
08/31-09/09	1994	0-27	Small	303-910	38	395	7	136	573	6	4	839	28	140	581	7

a Insufficient data.

burbot are caught in low proportions in both sections (less than 6%), but are slightly more predominant in the Tanana River section than in the Chena River section (Table 3). In the Tanana River section, the proportion of medium burbot has ranged from 0.47 to 0.78 since 1986. The 1994 estimate of 0.51 (SE = 0.03) is at the lower end of this range. Estimates of the proportions of medium burbot in the Chena River section are generally higher than those in the Tanana River section, and have ranged from 0.53 to 0.86 since 1988. The 1994 estimate was 0.76 (SE = 0.03).

Statistical comparisons among cumulative length frequency distributions for sample years 1988-1993 indicated that distributions were not homogenous in either river section (Evenson 1994). Plotted length frequencies indicate that distributions are more variable in the Tanana River section than in the Chena River section (Figures 3 and 4). This is likely attributed to the more variable times of sampling in the Tanana River section (See Table 1 for dates of sampling).

DISCUSSION

Accurate stock assessment of burbot in this system is difficult for a number of reasons. Because it is so large, only a small portion can be sampled during the open water period. Information from tag recoveries and from radio telemetry investigations have indicated that there is substantial interchange among burbot in river sections over the span of one year or more (Evenson 1990a, 1993b). Thus, stock structure (size composition and density) can vary annually as well as seasonally within a section as a result of movements into and out of the section Also, there are seasonal fluctuations in both catch rates and in size composition of sampled catches which can be attributed to changes in catchability. Similar fluctuations occur in lacustrine systems as well (Bernard et al. 1991) where immigration and emigration are unlikely.

Using mark-recapture methods to obtain estimates of abundance in index sections, while a more accurate method of stock assessment, has met with limited success in past investigations. Due to the low probability of capture using hoop traps, abundance estimates require substantial effort (twice as much as is needed to estimate mean CPUE) and in the past have been marginally precise (relative precision of seven estimates has ranged between 58%-87%; Evenson, 1993a).

To alleviate problems associated with seasonal fluctuations in catch rates, sampling was modified to cover a two week period instead of a one week period as was the case in past years. Standard errors of 1994 estimates were similar to those obtained in previous years. It is believed that this slightly longer sampling period will mitigate the effects of the seasonal variation in catchability and will provide CPUE and length composition estimates which are more comparable between years.

Sampling also needs to be conducted during the same time each year. In the Tanana River section sampling times have varied from early June to late August since 1986. Beginning in 1993, a standard sampling time of early to mid June was established in the Tanana River section. In the Chena River section, sampling times have been more consistent. With the exception of one sampling event in 1990, all sampling has taken place between late August and late September. If CPUE estimates are continued, these same time frames should be used in future years.

The presence of large burbot in a given area (especially in areas such as the sections in this study where substantial fishing harvest occurs) is a good indicator that stocks are not being over exploited. However, small hoop traps are not efficient at catching large burbot. In order to accurately estimate proportions of large burbot, larger samples than have been obtained in the past need to be collected. Large hoop traps, which are more efficient at catching large burbot, but more difficult to set should be considered for use. Set lines are also effective at catching large burbot. Monitoring the set line harvest may also provide a means for estimating proportions of large burbot.

Table 3.-Estimates of proportions of small, medium, and large burbot sampled in sections of the Tanana and Chena rivers, 1986-1994.

| Sampling Date	Year	River km Sampled	Hoop Trap Size	Catch Total	Catch Small	Proportion	SE	Catch Medium	Proportion	SE	Catch Large	Proportion	SE
Tanana River													
07/29-08/02	1986	334-352	Large	152	51	0.34	0.04	94	0.62	0.04	7	0.05	0.02
08/11-08/15	1986	334-352	Large	102	42	0.41	0.05	57	0.56	0.05	3	0.03	0.02
07/22-07/25	1987	339-354	Large	69	22	0.32	0.06	41	0.59	0.06	6	0.09	0.03
07/28-07/31	1987	339-354	Large	149	70	0.47	0.04	73	0.49	0.04	6	0.04	0.02
08/04-08/07	1987	339-354	Large	71	24	0.34	0.06	45	0.63	0.06	2	0.03	0.02
08/18-08/21	1987	339-354	Large	238	46	0.19	0.03	178	0.75	0.03	14	0.06	0.02
07/06-07/09	1988	312-376	Small	304	159	0.52	0.03	144	0.47	0.03	1	0	0
06/13-06/16	1989	317-374	Small	268	137	0.51	0.03	125	0.47	0.03	6	0.02	0.01
08/14-08/16	1990	344-376	Small	144	44	0.31	0.04	96	0.67	0.04	4	0.03	0.01
07/11-07/17	1991	336-360	Small	347	97	0.28	0.02	247	0.71	0.02	3	0.01	0
08/24-08/28	1992	336-360	Small	339	57	0.17	0.02	266	0.78	0.02	16	0.05	0.01
06/08-06/11	1993	336-360	Small	266	86	0.32	0.03	174	0.65	0.03	6	0.02	0.01
06/07-06/17	1994	336-360	Small	331	158	0.48	0.03	169	0.51	0.03	4	0.01	0.01
Chena River													
09/07-09/09	1988	0-24	Small	88	23	0.26	0.05	65	0.74	0.05	0	0	0
06/27-06/30	1989	0-24	Small	105	30	0.29	0.04	74	0.70	0.04	1	0.01	0.01
06/12-06/15	1990	0-24	Small	30	14	0.47	0.09	16	0.53	0.09	0	0	0
08/21-08/24	1990	0-24	Small	124	41	0.33	0.04	82	0.66	0.04	1	0.01	0.01
08/27-08/31	1990	0-24	Small	264	59	0.22	0.03	204	0.77	0.03	1	0	0
09/06-09/07	1990	0-24	Small	116	26	0.22	0.04	90	0.78	0.04	0	0	0
09/27-09/28	1990	0-24	Small	77	9	0.12	0.04	66	0.86	0.04	2	0.03	0.02
08/27-08/30	1991	0-24	Small	253	35	0.14	0.02	218	0.86	0.02	0	0	0
09/04-09/07	1991	0-24	Small	202	28	0.14	0.02	171	0.85	0.03	3	0.01	0.01
08/31-09/04	1992	0-24	Small	131	19	0.15	0.03	111	0.85	0.03	1	0.01	0.01
08/17-08/20	1993	0-24	Small	149	23	0.15	0.03	126	0.85	0.03	0	0	0
08/31-09/09	1994	0-27	Small	178	38	0.21	0.03	136	0.76	0.03	4	0.02	0.01

TANANA RIVER
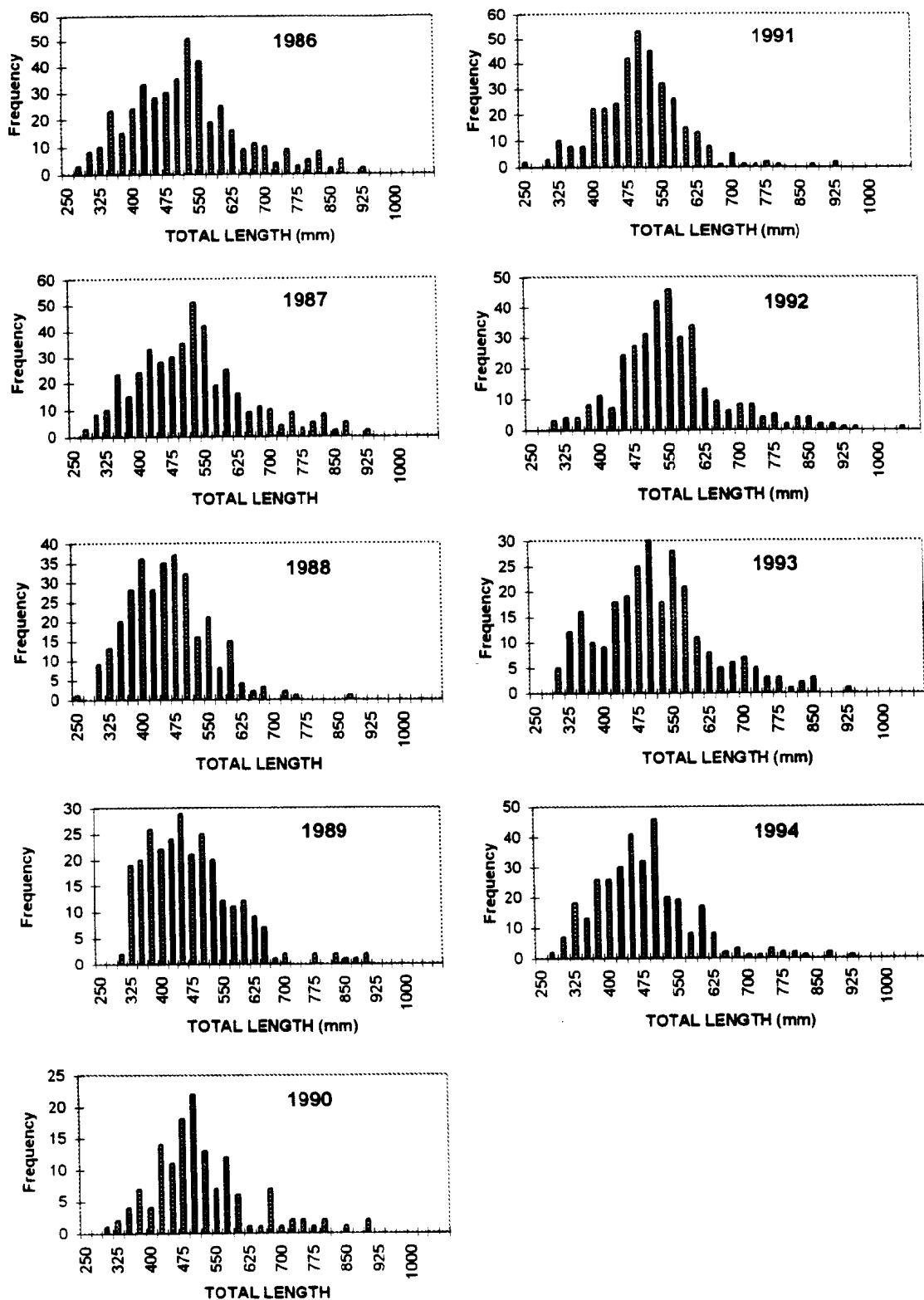
Figure 3.-Length frequency distributions of burbot sampled in the Tanana River, 1986-1994.
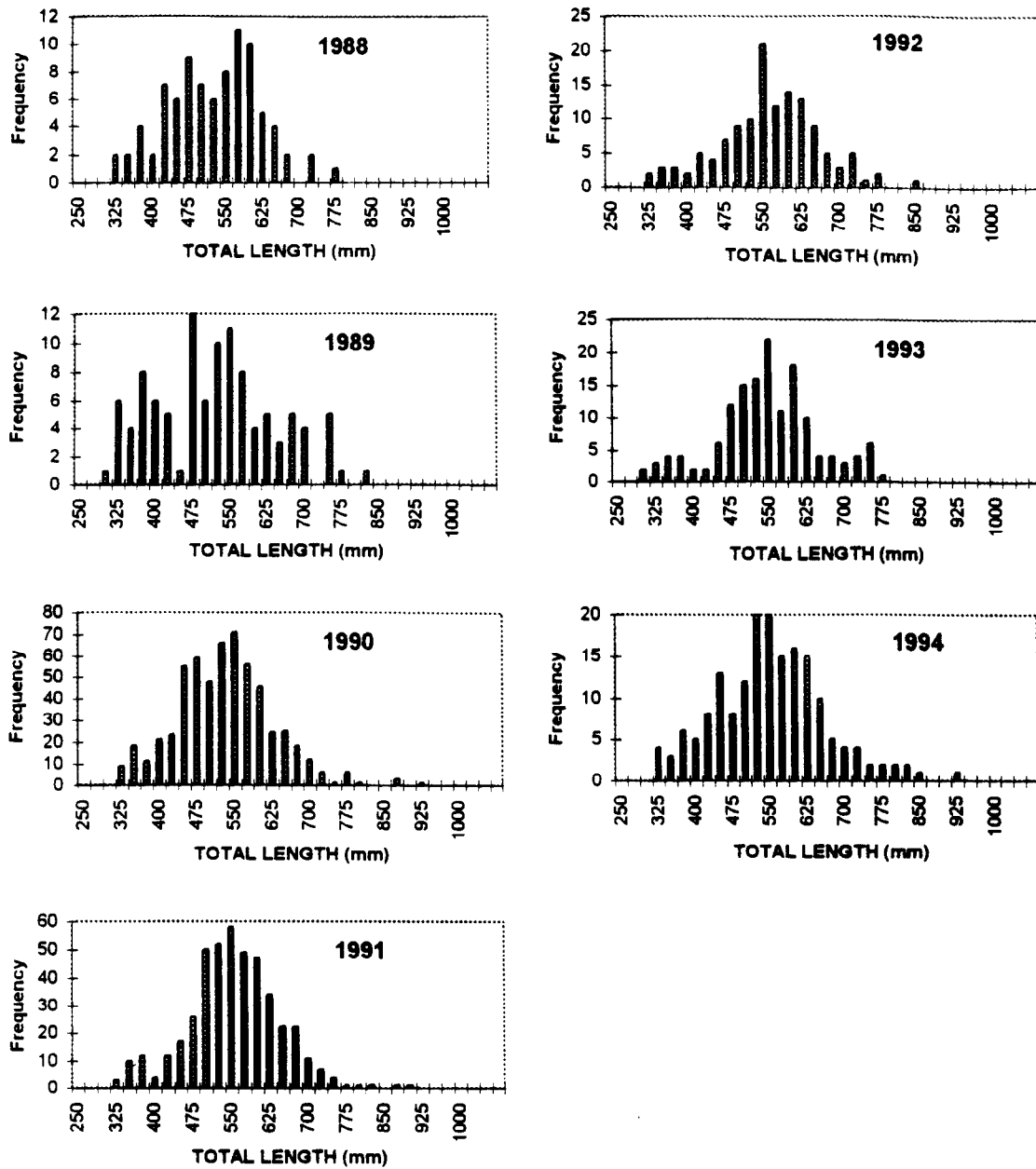
11

CHENA RIVER

Figure 4.-Length frequency distributions of burbot sampled in the Chena River, 1988-1994.

CHAPTER 2. CATCH-AGE ANALYSIS OF BURBOT IN THE TANANA RIVER DRAINAGE

INTRODUCTION

Estimates of mean CPUE are difficult to interpret due to seasonal variations in catch rate and composition. Additionally, estimates of mean CPUE for burbot in the Tanana River have not correlated well with mark/recapture estimates of abundance (Evenson 1993a). Catch-age analysis was examined as an alternative method of estimating abundance of burbot in the Tanana River. Catch-age analysis uses an age-structured approach to population abundance estimation by combining harvest at age information with auxiliary data to generate abundance estimates by year and age class.

METHODS

The computer program CAGEAN (Deriso et al. 1985) was used to solve for a non-linear least-squares solution (Marquardt 1963) to parameters related to the population and sport fishery. CAGEAN couples a simulation model of the population dynamics with data generated from various estimation procedures, and compares predicted parameters with observed data. Using a minimization criterion, CAGEAN seeks the set of parameters that minimize differences between predicted and observed values. Standard deviations of calculated parameter estimates are obtained using Monte Carlo (bootstrap) simulation. Two data sources were used: harvest estimates for the Tanana River from 1987 - 1993[1] (Mills 1988 - 1994); and estimated age composition of the harvest (ages 4 - 16+) from angler-returned carcasses, and catch sampling. Auxiliary information in the form of fishing effort (angler days; Mills 1988 - 1994) was introduced to stabilize parameter estimation. Initial values generated by CAGEAN were used for initial parameter estimates. Input files for the CAGEAN analysis are given in Appendix B.

Notation

Notation used to define parameters follows. A caret ($^\wedge$) is used to denote parameter estimates from data (such as observed age composition, and harvest from the statewide harvest survey); parameter estimates from catch-age models are topped with ($^\sim$).

$\hat{H}_{a,y}$ = harvest by age in year y as estimated from samples of otoliths and information from the statewide harvest survey,

$\hat{p}_a$ = observed proportion of age a fish in the sample,

$\hat{L}_a$ = length at age a,

$\hat{L}\infty$ = asymptotic length of burbot,

$\hat{K}$ = von Bertalanffy growth coefficient,

$\hat{t}_o$ = theoretical age at length zero,

$\hat{t}_{mb}$ = 0.38 of the maximum observed age,

$\hat{M}$ = instantaneous natural mortality,

$\hat{Z}$ = estimated total mortality,

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[1] No harvest samples were collected for 1990 so harvest at age information is missing for that year.

$\hat{F}$ = estimated fishing mortality,

$\hat{E}_y$ = calculated fishing effort in year y for burbot,

$\hat{AD}$ = estimated angler days from the statewide harvest survey,

$\tilde{\varepsilon}_y$ = error in relationship between fishing mortality and fishing effort in year y,

q = catchability coefficient,

$\tilde{N}_{a,y}$ = estimated number of fish in the cohort at age a in year y in the catch-age model,

λ = effort lambda or weighting factor for effort,

μ = exploitation fraction or rate, and

$\tilde{H}_{a,y}$ = estimated harvest of fish of age a in year y from the catch-age model.

Harvest at Age

Total harvests estimated from the statewide harvest survey (Mills 1988 - 1994) were computed by summing harvests from all discrete flowing waters draining into the Tanana River[2] (see Figure 5). Harvest at age from 1987-89 and from 1991-93 was estimated by multiplying the estimated proportion by age class from angler-returned carcasses and catch sampling (Table 4) and the estimated harvest from the statewide harvest survey (Table 5):

$$\hat{H}_{a,y} = \hat{H}_y \hat{p}_a. \tag{7}$$

Ages were determined from otoliths collected from burbot harvested primarily in the winter fishery. Most samples were collected from the middle mainstem Tanana River near Fairbanks and the lower Chena River. The majority of the annual harvest (ranging from 60 to 80%) occurs in the middle portion of the Tanana River drainage (see Figure 6 and Appendix C). For this analysis, it was assumed that these age samples were representative of the total annual harvests within the Tanana River drainage.

Age Determination

A pair of otoliths (sagittae bones) were removed from each fish for age analysis. A randomly chosen sample of 56 otolith pairs was used to compare precision of whole surface readings versus readings from sectioned and toasted otoliths. Surface-read otoliths were stored in a glycerin and alcohol solution for one day prior to reading. To prepare toasted sections, otoliths were broken through the origin along the latitudinal axis. The broken surface was polished using a grinding tool. The otolith was then dipped in cedar wood oil and passed over an alcohol flame and toasted until a uniform brown color was

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[2] Areas in the statewide harvest survey which were summed to provide estimates of total harvest were: upper and lower Chena River, lower, middle and upper Tanana River, Nenana River, Salcha River, Shaw Creek, Goodpaster River, Piledriver Slough, Chatanika River, Delta Clearwater River, Minto Flats, and other streams in the Tanana River drainage not specifically listed in the statewide harvest survey.

YUKON RIVER

Lower Section   Middle Section

Tanana

TANANA RIVER

Manley
Fish Lake
Minto Flats
Tolovana R.
Minto
Talalina R.
Chatanika R.
Goldstream Ck.
Fairbanks
Chena R.
Chena Lks.
Badger Sl.
Piledriver Sl.
Caribou Ck.
Selche R.

Kantishna R.

W. Twin
Wien Lake
E. Twin lakes

Toklat River
Sunshine R.
Teklanika R.
Nenana River
Wood R.
Nenana

Harding Lk.
Birch Lk.
Quartz Lk.
Shaw Ck.
Goodpaster R.
Upper Section

Richardson Clearwater
Volkmar R.
Healy R.
Delta Clearwater
Healy Lk.
George Lk.
Billy Ck.

Beaver R.
Moose Creek

Cantwell

Delta R.
Johnson R.
Mansfield Ck.

Delta Junction

Tok
Tok R.
Northway

Fielding Lk.
Tangle Lks.
Mineral Lk.
Little Tok R.

Fish Creek

Jack Lk.
Nabesna R.

Chisana R.

0   50 km

Figure 5.-Map of the Tanana River drainage, with the lower, middle and upper sections
of the Tanana River demarcated.

Table 4.-Proportion at age of burbot, Tanana River, estimated from carcasses collected during the winter sport harvest, for the years 1987-89, and 1991-93.

Age	Year							Sample Size (n)
	1987	1988	1989	1990[a]	1991	1992	1993	
4	0.000	0.018	0.008	0.000	0.000	0.002	0.000	5
5	0.059	0.041	0.030	0.000	0.025	0.040	0.000	44
6	0.103	0.082	0.053	0.000	0.105	0.094	0.009	108
7	0.132	0.146	0.165	0.000	0.160	0.154	0.034	186
8	0.059	0.123	0.143	0.000	0.147	0.149	0.034	168
9	0.132	0.175	0.105	0.000	0.126	0.128	0.154	174
10	0.059	0.129	0.135	0.000	0.134	0.131	0.145	168
11	0.088	0.123	0.135	0.000	0.067	0.112	0.205	149
12	0.132	0.088	0.083	0.000	0.113	0.075	0.111	118
13	0.059	0.023	0.068	0.000	0.076	0.047	0.111	75
14	0.059	0.023	0.045	0.000	0.025	0.028	0.051	42
15	0.044	0.018	0.023	0.000	0.017	0.023	0.060	33
16+	0.074	0.012	0.008	0.000	0.004	0.017	0.085	29
Total	68	171	133	0.000	238	572	117	1,299

[a] No samples for age determination were collected in 1990.

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Table 5.-Estimated harvest of burbot in flowing waters of the Tanana River[a] drainage from the statewide harvest survey, 1987-1993.

Year	Harvest[b] ($\hat{H}$)
1987	3,749
1988	3,406
1989	4,225
1990	3,579
1991	2,187
1992	3,231
1993	5,181

[a] Summed from: lower and upper Chena River, lower, middle, and upper Tanana River, Nenana River, Salcha River, Shaw Creek, Goodpaster River, Piledriver Slough, Chatanika River, Delta Clearwater River, Minto Flats, and other flowing waters not specifically listed in the statewide harvest survey.

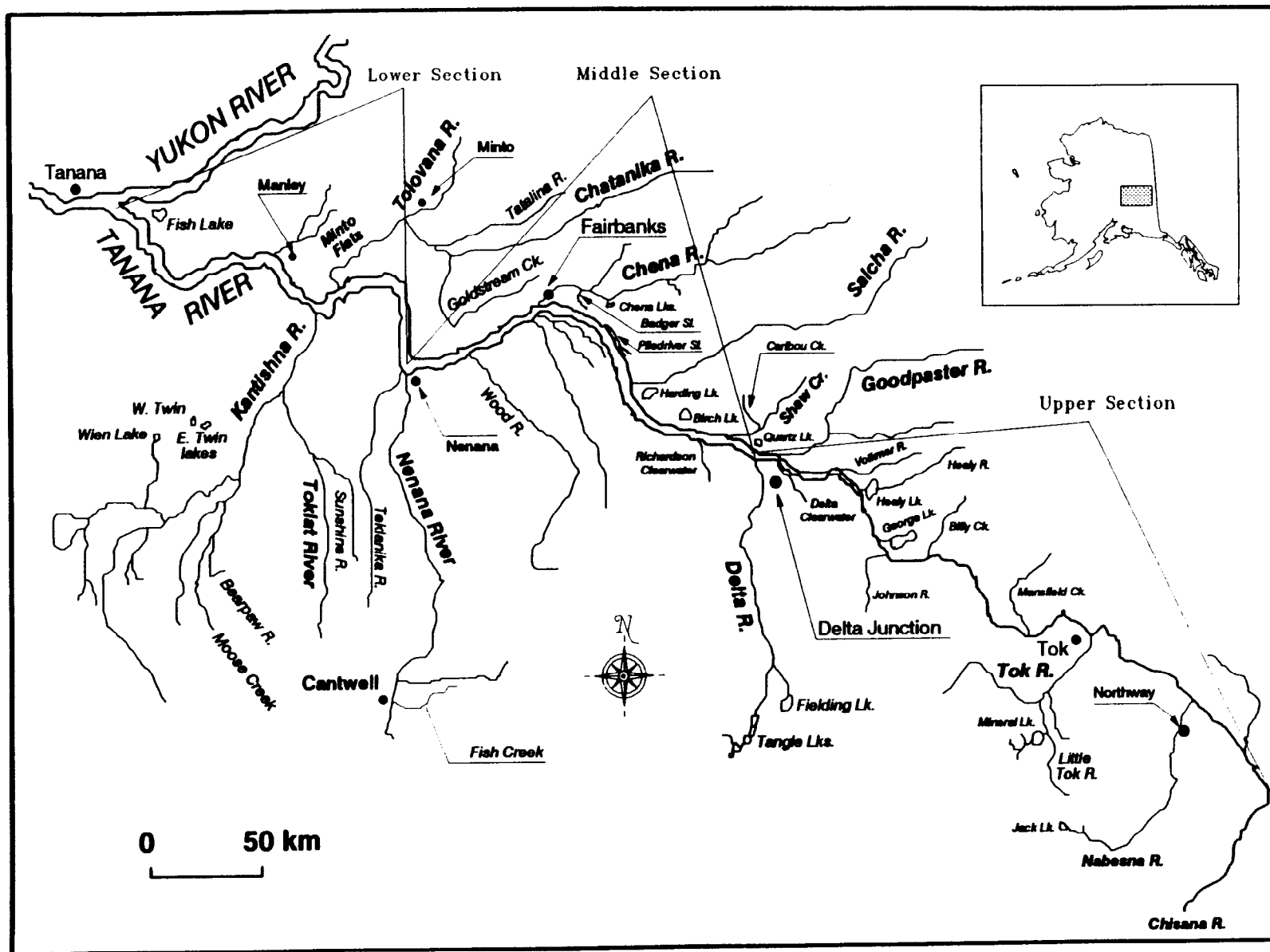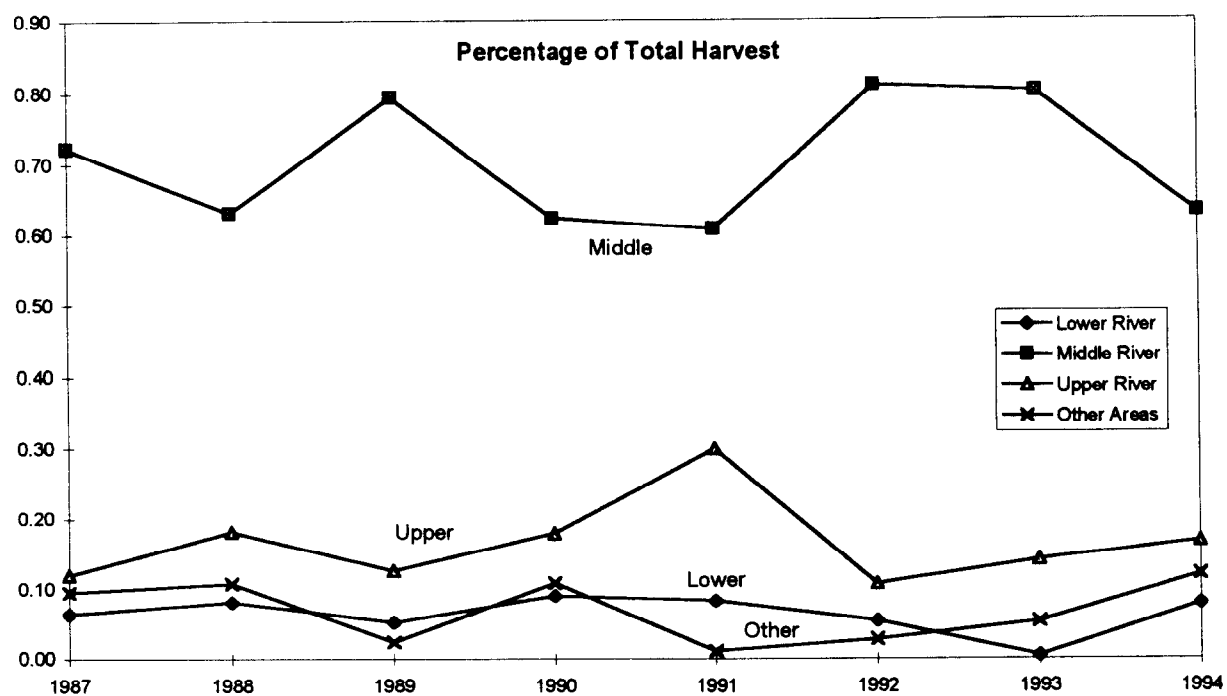[b] Standard errors are not currently available.

Figure 6.-Percentage of the annual burbot harvest from the Tanana River drainage by section (see Figure 5), and "other" streams, as identified in the statewide harvest survey.

achieved. Both whole and sectioned otoliths were viewed under a binocular dissecting microscope under reflected light.

Each pair was read by the same reader three times using each technique. Otolith pairs were chosen randomly during each reading without knowledge of prior age assignments. Ages assigned to sectioned and toasted otoliths were significantly more variable than were ages assigned examining whole surfaces (F test of equal variance, $F_{55,55} = 3.47$, $P < 0.001$). Mean ages derived from each method (all readings combined) did not differ significantly (8.9 years for sectioned and toasted vs. 8.7 years for whole surface readings). Therefore, the remaining otoliths were all aged by examining whole otolith surfaces.

Gear Description and Vulnerability

Anglers typically use fish bait to capture burbot. The baited hook and lines are fished both actively (rod and reel) or passively using lines set over night. Regulations require a minimum hook size (distance between point of hook and shank) of 19 mm (3/4 inch). Most samples for this analysis were collected from anglers fishing during the winter using set-lines.

The range of ages used in the analysis was 4 - 16+. Although not fully recruited to the fishery, burbot of age 4 begin to show in significant numbers in harvest samples. Bias in determining age increases with age. Therefore, burbot of age 16 and older were pooled into a single 16+ group (Deriso et al. 1989). Fournier and Archibald (1982) recommend pooling older age classes for catch-age analysis. The age of full vulnerability to the fishery was determined to be 9 from initial CAGEAN model output (Figure 7).

Catchability

Regulations (i.e. gear restrictions, seasons, and bag limits) for this sport fishery were constant during all years of analysis (1987-1993). Additionally, because the fishery occurs year round, environmental factors which might influence catchability are minimal compared to discrete fisheries. For these reasons catchability was assumed to be constant among all years.

Instantaneous Natural Mortality

The von Bertalanffy growth model (von Bertalanffy 1938) was used in the estimation of the following life history parameters: K, L_∞, and t_0. Estimates of these parameters were obtained using a modified Marquardt non-linear least squares procedure contained in a FORTRAN program. The equation used was:

$$\hat{L}_a = \hat{L}_\infty (1 - e^{-\hat{K}(a - \hat{t}_0)}).$$
(8)

The oldest age consistently present in samples was 16, which was used as the maximum age of burbot for purposes of estimating instantaneous natural mortality[3]. Alverson and Carney (1975) have shown that the age at which a cohort reaches its maximum biomass ($\hat{t}_{mb}$) is about 0.38 of the maximum age. Alverson and Carney reasoned that because the time at which cohort biomass is maximized is a function of growth and mortality, natural mortality could be estimated by:

$$\hat{M} = \frac{3\hat{K}}{e^{\hat{t}_{mb}\hat{K}} - 1}.$$
(9)

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[3] Maximum age should be determined through observation of an unfished population; however Tanana River burbot are not heavily exploited. Thus, relatively little error will be introduced by assuming that maximum age of fish in samples have not been reduced through exploitation.
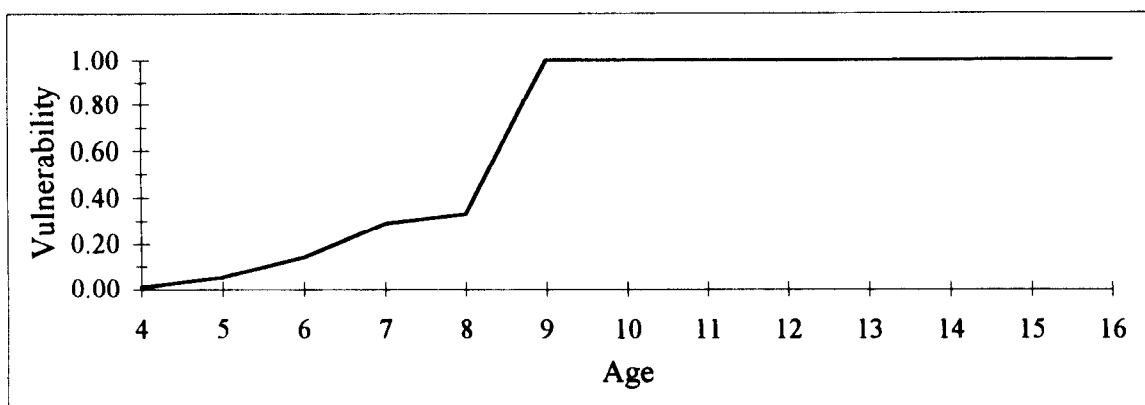
Figure 7.-Estimated gear vulnerability at age for the burbot sport fishery in the Tanana River.

Equation 8 was used with results from the von Bertalanffy models for the years in which individual age data were available (1987 - 1993). The average was used as the estimate of natural mortality for all ages.

Total mortality was estimated as:

$$\hat{Z}_{a,y} = \hat{F}_{a,y} + \hat{M}_{a,y}.$$

(10)

Fishing Effort Source File, Effort Lambda

Estimated total angler days from the statewide harvest survey could not be used as a direct measure of fishing effort because data are collected by waterbody, not by species targeted. To obtain an estimate of fishing effort it was assumed that the fraction of burbot harvested from the mainstem Tanana River relative to total fish harvested is proportional to the fraction of angler days expended for burbot, relative to total angler days:

$$\hat{E}_y = \frac{\hat{H}_{burbot,y}}{\hat{H}_{total,y}} \times \hat{AD}_y$$

(11)

Fishing effort in terms of angler days was used as an auxiliary data source to aid in the estimation of fishing mortality.

Because there is no direct measure of effort for the burbot sport fishery in the Tanana River, there is less confidence in the reliability of effort information, as opposed to harvest information, so an upper limit of 0.9 was imposed on the search for the effort lambda (λ). An effort lambda of 0.4 was derived by running CAGEAN models over a range of lambdas (0.1 to 0.9 at 0.1 increments) and examining: (1) the stability of the fishing mortality, after Deriso et al. (1985); (2) total abundance and variance estimates; and, (3) the residual root mean square (unexplained variability).

Error Structure

Bootstrap resampling (Efron and Tibshirani 1993) was used to obtain an idea of the underlying error distributions for harvest[4]. Because visual inspection of the resulting distributions indicated slight skewness in 1991 and 1992 (Figure 8), harvests at age were assumed to be log-normally distributed. This is similar to other catch-age analyses (Deriso et al. 1985, Doubleday 1976) which assume logarithms of harvest age compositions to be normally distributed. Angler days (fishing effort) is measured with error, so the relationship between fishing effort and fishing mortality is not exact. The difference between these two terms can be modeled with the log-normal distribution:

$$\tilde{\varepsilon}_y = \ln\hat{F}_y - \ln(q\hat{E}_y).$$

(12)

Population Dynamic Models

Because the Tanana River burbot fishery occurs essentially year-round, and fishing mortality is continuous, the following equation was used to model abundance of one cohort to the next year:

$$\tilde{N}_{a+1,y+1} = \tilde{N}_{a,y} e^{-Z_{a,y}}.$$

(13)

Older ages were pooled into a single group (16+) and the abundance of this group was calculated as:

$$\tilde{N}_{16+,y+1} = \tilde{N}_{15,y} e^{-Z15,y} + \tilde{N}_{16+,y} e^{-Z16+,y}.$$

(14)

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[4] Only files of bootstrap iterations of harvest for the years 1991 - 1993 were available.
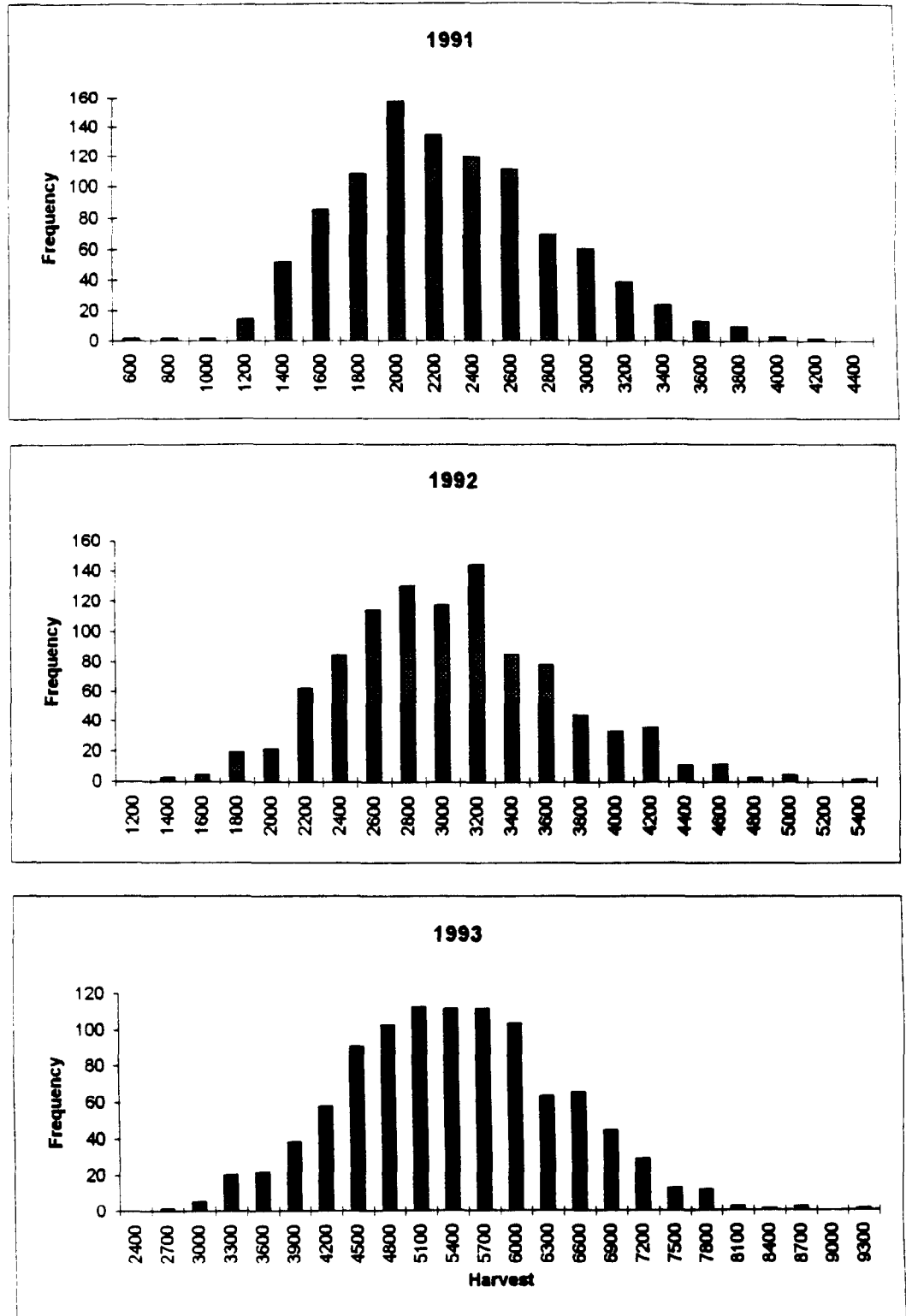
Figure 8.-Bootstrap distributions of burbot harvest in the Tanana River, 1991-1993.

Estimated harvest was modeled as a function of:

$$\tilde{H}_{a,y} = \mu_{a,y} \tilde{N}_{a,y} \tag{15}$$

which assumes that exploitation and vulnerability are separable.

Statistical Models

A given sum of squares component (SSQ) represents estimation error. The sum of squares which compared differences between observed and estimated log-harvest at age was computed as:

$$SSQ_{harvest} = \sum_{y,a} [(\ln \tilde{H}_{y,a}) - (\ln \hat{H}_{y,a})]^2. \tag{16}$$

The sum of squares which modeled the inexact relationship between fishing effort and fishing mortality was computed as:

$$SSQ_{effort} = \lambda \sum_{y} (\tilde{\varepsilon}_y)^2. \tag{17}$$

Objective Function

The objective is to minimize total prediction error (O_{total}) which is computed by adding each of the error components:

$$O_{total} = SSQ_{harvest} + SSQ_{effort}. \tag{18}$$

The value of the objective function is to measure how well the model fits observed data. A smaller objective function signifies a better fit.

RESULTS

Estimated Abundance

Exploitable abundance, the number of fish that are potentially vulnerable to the fishery, decreases from 1987 to 1993 (Figure 9, Table 6). As expected, the coefficient of variation for the most recent (1993) abundance estimate is high (31%) compared to prior years because cohort information for CAGEAN estimation is missing after 1993.

Pre-fishery abundance is defined as fish at large, without consideration of the gear selectivity adjustment. Pre-fishery abundance at age estimates decrease markedly from 1987 to 1993 for young, partially-recruited fish (Table 7 and Figure 10). Whereas, abundance of older fish (ages 12+) does not vary to the same extent during this time frame. Thus, the decreasing trend in total exploitable abundance may be more attributable to decreased numbers of young, partially-recruited fish than to a substantial depletion of older, large fish.

Estimated Fishing Mortality

Overall, estimated fishing mortality is relatively low. Estimated fishing mortality of fully recruited burbot (ages 9+) increases from 1991 through 1993 (Figure 11), similar to the trend in harvest estimated from the statewide harvest survey (Table 5). Fishing mortality for fully recruited burbot in 1990 as estimated by CAGEAN is quite low (0.0149) compared to other years (Table 8). The 1990
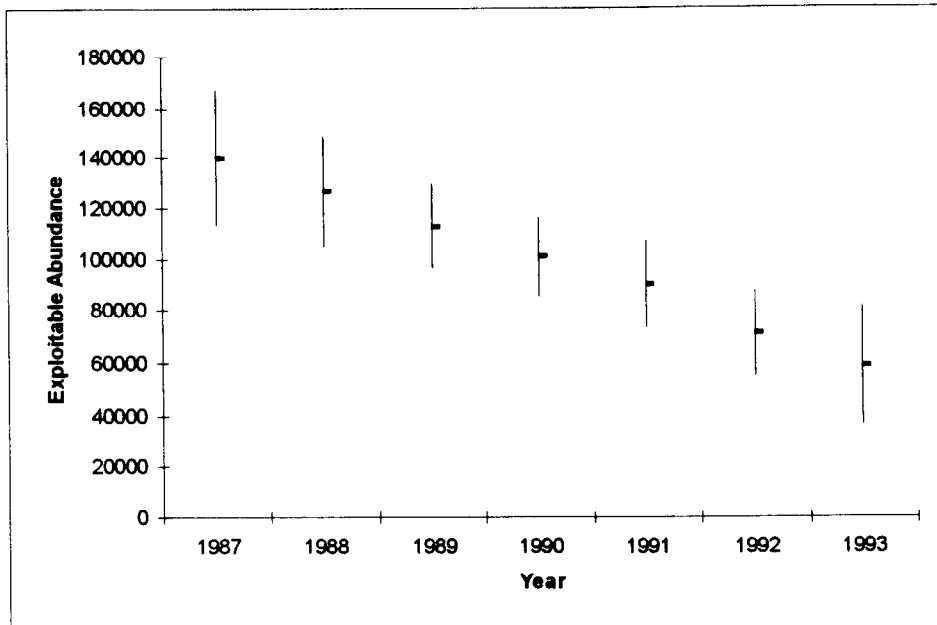
Figure 9.-Total estimated exploitable abundance ($\pm$ 1 SD) of burbot in the Tanana River by year.

Table 6.-Estimated and bootstrapped mean exploitable abundance with coefficients of variation for Tanana River burbot, 1987-1993.

Year	Estimated Exploitable Abundance	Mean Exploitable Abundance	CV
1987	140,125	153,406	17.6
1988	126,654	137,947	16.0
1989	112,773	123,279	13.6
1990	100,839	112,801	13.7
1991	89,952	102,728	16.4
1992	71,046	89,666	19.9
1993	58,722	73,655	31.0

Table 7.-Estimated pre-fishery abundance at age $(\tilde{N}_{a,y})$ for burbot in the Tanana River, 1987-1993.

Year	Age												
	4	5	6	7	8	9	10	11	12	13	14	15	16+
1987	96,088	126,898	99,246	58,950	41,890	34,051	17,725	15,044	6,773	4,017	3,898	1,713	4,617
1988	167,875	61,254	80,757	62,950	37,189	26,385	20,924	10,891	9,244	4,162	2,468	2,395	3,890
1989	107,563	107,018	38,987	51,243	39,743	23,445	16,257	12,892	6,711	5,696	2,564	1,521	3,872
1990	62,668	68,564	68,071	24,695	32,236	24,952	14,266	9,892	7,845	4,083	3,466	1,560	3,282
1991	24,628	39,954	43,675	43,285	15,659	20,424	15,607	8,923	6,188	4,907	2,554	2,168	3,029
1992	4,277	15,701	25,440	27,741	27,386	9,896	12,676	9,687	5,538	3,840	3,045	1,585	3,225
1993	5,476	2,726	9,978	16,076	17,369	17,100	5,923	7,588	5,798	3,315	2,299	1,823	2,880
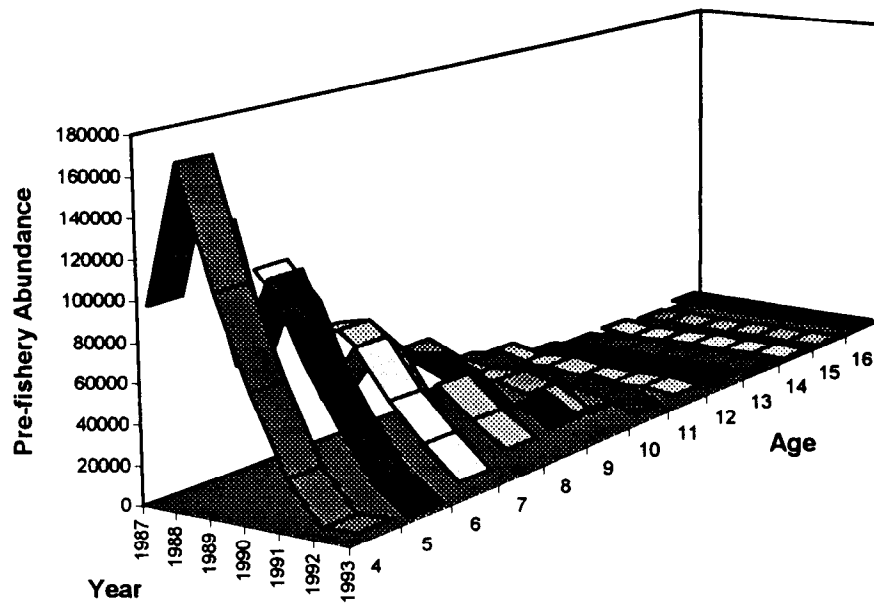
Figure 10.-Estimated pre-fishery abundance $(\tilde{N}_{a,y})$ at age for burbot in the Tanana River by year.
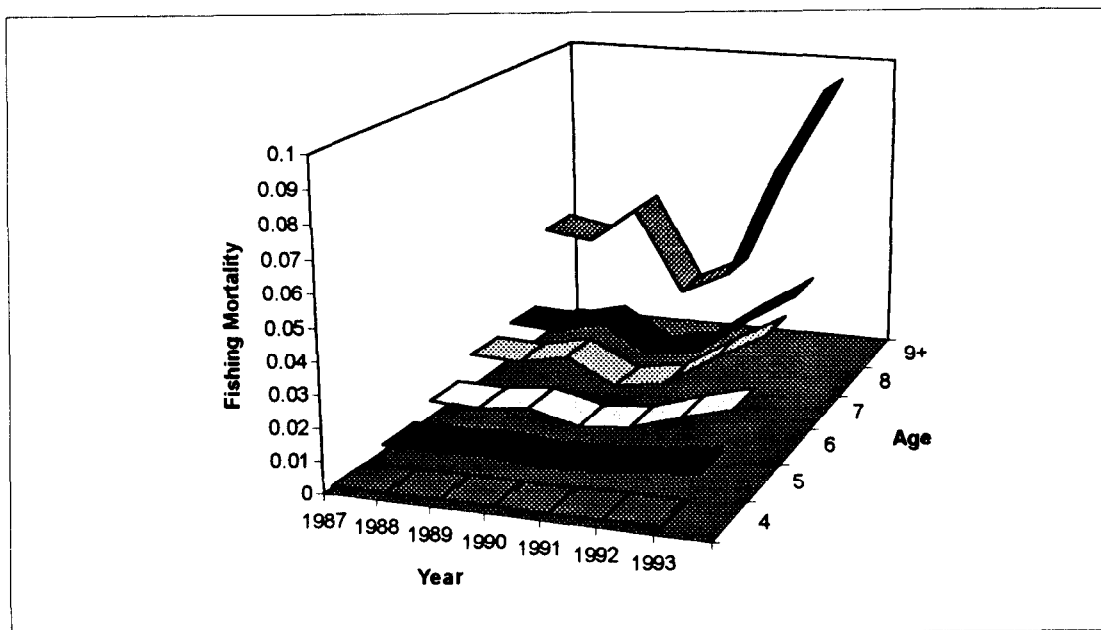
Figure 11.-Estimated fishing mortality at age for burbot in the Tanana River by year.

Table 8.-Estimated fishing mortality at age for burbot in the Tanana River, 1987-1993.

Year	Age												
	4	5	6	7	8	9	10	11	12	13	14	15	16+
1987	.000243	.001934	.005261	.010681	.012258	.036989	.036989	.036989	.036989	.036989	.036989	.036989	.036989
1988	.000225	.001792	.004876	.009899	.011359	.034278	.034278	.034278	.034278	.034278	.034278	.034278	.034278
1989	.000307	.002444	.006650	.013502	.015494	.046755	.046755	.046755	.046755	.046755	.046755	.046755	.046755
1990	.000126	.001004	.002732	.005546	.006364	.019205	.019205	.019205	.019205	.019205	.019205	.019205	.019205
1991	.000177	.001412	.003842	.007800	.008951	.027010	.027010	.027010	.027010	.027010	.027010	.027010	.027010
1992	.000415	.003302	.008985	.018242	.020934	.063169	.063169	.063169	.063169	.063169	.063169	.063169	.063169
1993	.000617	.004905	.013345	.027093	.031091	.093821	.093821	.093821	.093821	.093821	.093821	.093821	.093821

fishing mortality estimate is likely in error. Because the effort parameter has a significant influence upon the estimation of fishing mortality in CAGEAN, the problem may be in part attributable to the effort estimate for that year. A lack of catch samples for 1990 has also undoubtedly contributed error to the fishing mortality estimate.

Residual and Bias Analysis

Residuals from effort and harvest were visually examined for trend and showed no consistent pattern (Figure 12). The effort residual for 1990 is high and indicates a large difference between observed and expected effort in that year. Either fishing effort was constrained in 1990 due to unusual circumstances (i.e., weather) or, as noted above, observed fishing effort for 1990 is somewhat in error.

Based on the difference between estimated and mean bootstrapped exploitable abundance, minimal (10 to 15%) bias was detected from 1987 to 1993 (Figure 13). Greater (25%) bias was noted in 1993.

DISCUSSION

Catch-age analysis appears to be a promising method for estimating trends in abundance and fishing mortality for burbot in Tanana River drainage. Additionally, recruitment estimates can be used in modeling exploitation scenarios, thereby providing a tool for evaluating harvest policy. Prior to catch-age analysis, mark-recapture estimates for burbot in the Tanana River were attempted (Evenson 1993a), but were costly and incompletely characterized the total exploitable population. Catch per unit effort studies (Evenson 1993a) do not provide adequate information to monitor trends in recruitment and abundance. For example, the CPUE estimates from 1994 in the Tanana and Chena river sections are within the range of estimates from previous years and suggest no downward trend in exploitable abundance such as indicated using catch-age analysis.

The decreasing trend in total exploitable abundance from 1987 to 1993 may result from several causes. One cause is decreased numbers of young, partially-recruited fish. CAGEAN estimates of declines in pre-fishery abundance at ages 4 - 6 (see Figure 10) after 1989 are generally corroborated by examination of length frequency distributions obtained during CPUE sampling (see Figure 4). The frequency of burbot < 450 mm TL (corresponding to approximately age 6 or younger) decreases substantially after 1989. Another cause may be an artifice of CAGEAN. In a retrospective catch-age analysis of Pacific halibut, Parma (1993) found that estimates of stock abundance tended to be autocorrelated, with the stock consistently being overestimated or underestimated for a series of consecutive years. While the catch-age analysis of burbot in the Tanana River may suffer from retrospective errors similar to those found by Parma for Pacific halibut, an ICES working group (Anonymous 1991) pointed out that retrospective errors are stock-specific. That is, the causes for error are independent of the catch-age method used. Additional causes of a decreasing trend in Tanana River burbot abundance might be due to errors in the data, such as catch misreporting, or a misspecification of natural mortality. It is also possible that the decreasing trend in total exploitable abundance is a localized phenomena resulting from age samples which, for the most part, were collected near Fairbanks, and is thus not representative of the entire population. The CAGEAN model should be updated with 1994 catch-age estimates and re-run to corroborate trend information. Trends in exploitable abundance can be examined for errors by annually updating the catch-age model, and by reviewing independent indices, such as trends in harvest and length frequency distributions. Estimated sport harvest has fluctuated around 3,400 burbot from 1987-1992 (only increasing in 1993), so harvest information does not account for the decreasing trend in exploitable abundance.
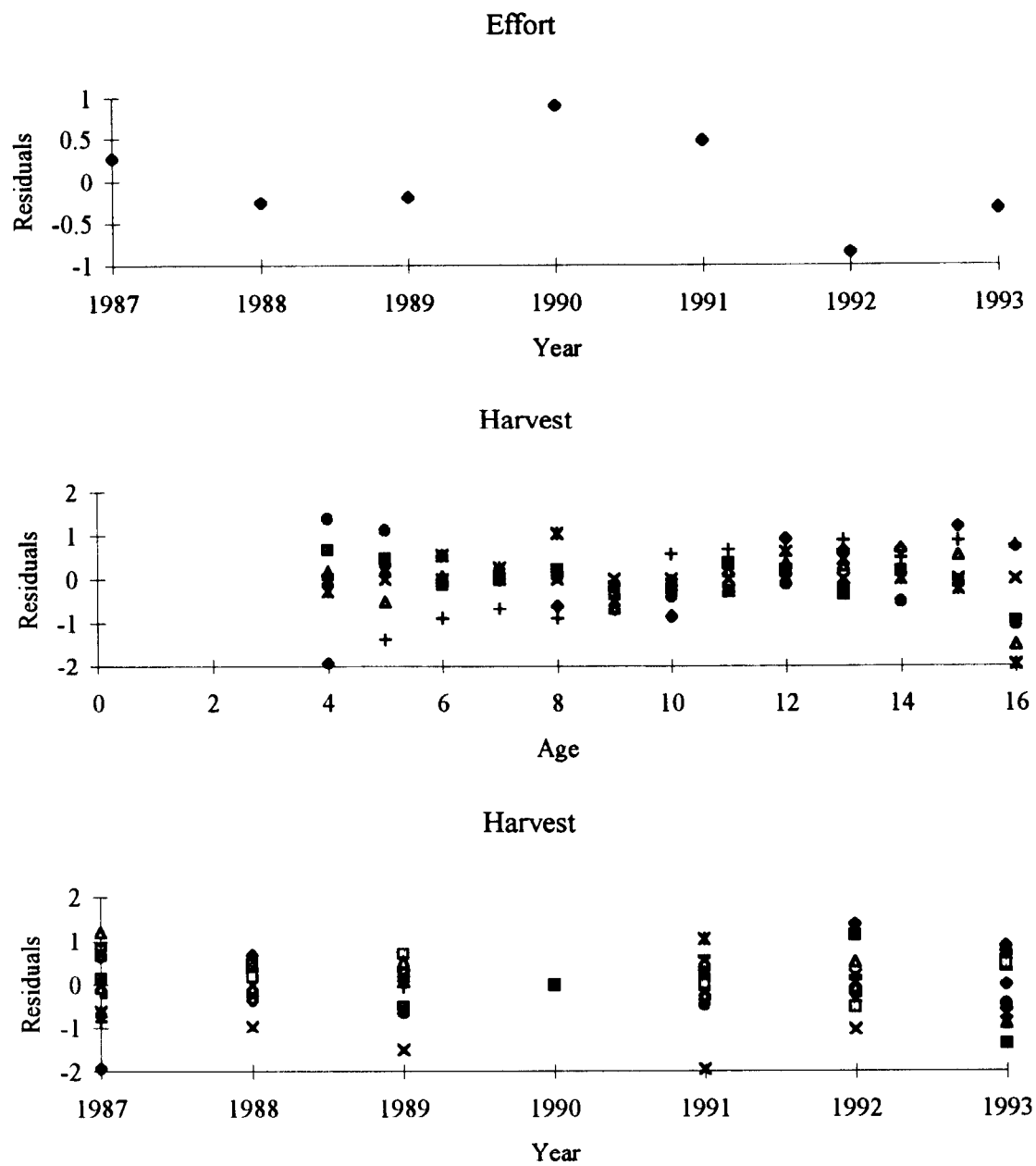
30

Effort

Harvest

Harvest

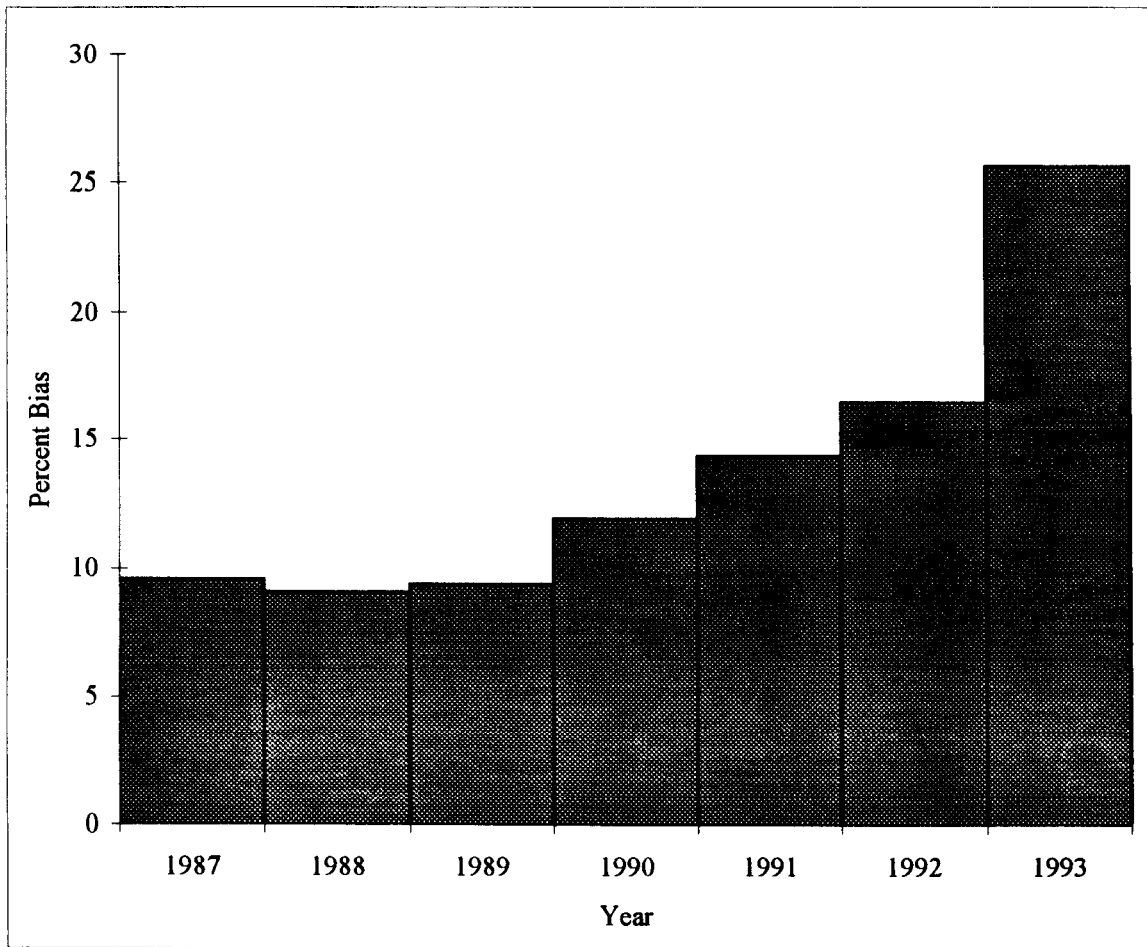Figure 12.-Residuals of effort and harvest estimated from CAGEAN.

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Figure 13.-Percent difference (bias) of the bootstrapped mean from estimated exploitable abundance of burbot in the Tanana River, by year.

The catch-age analysis used in this study was constrained in several respects, including indirect measures of effort, and the catch sampling program for harvest at age information. In order to improve upon the catch-age model, direct measures of effort should be incorporated. Beginning in 1995, fishing effort by species will be estimated by the statewide harvest survey. These direct measures of effort will undoubtedly increase the precision of parameter estimates.

Of paramount importance is the need to improve the catch sampling program. A catch sampling program should be designed with specific sample sizes given objective criteria. Because of the nature of the sport fishery for burbot in the Tanana River drainage, the catch-sampling program will require expense commensurate with a wide-spread, sporadic fishery.

ACKNOWLEDGMENTS

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Appendix A

Appendix A.-Data files regarding burbot stock assessment in sections of the Tanana and Chena rivers archived by the Research and Technical Services of the Alaska Department of Fish and Game-Sport Fish Division[a].

Year	Data File	River (River Kilometer)
1986	U0275ETA.DTA	Tanana River (334-352)
1986	U0275ETB.DTA	Tanana River (334-352)
1986	U0275ETC.DTA	Tanana River (334-352)
1987	U0275CBA.DTA	Tanana River (339-354)
1987	U0275DBA.DTA	Tanana River (339-354)
1987	U0275EBA.DTA	Tanana River (339-354)
1987	U0275EBB.DTA	Tanana River (339-354)
1987	U0275EBC.DTA	Tanana River (339-354)
1988	U275CLA8.DTA	Tanana River (312-376)
1988	U0020LA8.DTA	Chena River (0-24)
1989	U275BLA9.DTA	Tanana River (317-374)
1989	U0020LA1.DTA	Chena River (0-40)
1990	U2750HA0.DTA	Tanana River (344-376)
1990	U0020HA0.DTA	Chena River (0-24)
1990	U0020HB0.DTA	Chena River (0-24)
1990	U0020HC0.DTA	Chena River (0-24)
1990	U0020HD0.DTA	Chena River (0-24)
1990	U0020HE0.DTA	Chena River (0-24)
1991	U2750HA1.DTA	Tanana River (336-360)
1991	U0020HA1.DTA	Chena River (0-24)
1992	U2750HA2.DTA	Tanana River (336-360)
1992	U0020HA2.DTA	Chena River (0-24)
1993	U2750HA3.DTA	Tanana River (336-360)
1993	U0210HA3.DTA	Chena River (0-24)
1994	U2750HA4.DTA	Tanana River (336-360)
1994	U0020HA4.DTA	Chena River (0-24)

[a] Files for other river sections sampled since 1986 are given in Evenson (1994[)]

APPENDIX B. COMMAND AND DATA FILES USED TO RUN CAGEAN

Appendix B1.-Command File: initial values.

TANANA BURBOT 1987-1993

caginit.out

1987 1993	range of years for analysis
4 16	range of ages for analysis
1	number of gear types
1	code number for gear type 1
1	number of selectivity groups
1987 1993	range of years of first selectivity group
9 16	range of ages of full selectivity first group
1	number of catchability groups
1987 1993	first and last years of catchability group 1
100	TIMES TO DO THE BOOT
0.45000	NATURAL MORTALITY
0.0	TO STOP NATURAL MORTALITIES
OK	OK TO PARAMETERS OK
Y	TO FULL LISTING
0	no fixing of variables - fix catchability
1	pooling of data (1=YES)

catch.dat

weight.dat

effort.dat

.4	EFFORT OR CATCHABILITY LAMBDA GR TYPE 1

NONE

bbinits.dat

NONE

kboot.out

Y	PRINT LABELED RESIDS
Y	PRINT RESIDUALS

Appendix B2.-Command File: first run.

TANANA BURBOT 1987-1993

cagfrst.out

1987 1993	range of years for analysis
4 16	range of ages for analysis
1	number of gear types
1	code number for gear type 1
1	number of selectivity groups
1987 1993	range of years of first selectivity group
7 16	range of ages of full selectivity first group
1	number of catchability groups
1987 1993	first and last years of catchability group 1
100	TIMES TO DO THE BOOT
0.45000	NATURAL MORTALITY
0.0	TO STOP NATURAL MORTALITIES
OK	OK TO PARAMETERS OK
Y	TO FULL LISTING
0	no fixing of variables - fix catchability
1	pooling of data (1=YES)
catch.dat	
weight.dat	
effort.dat	
0.5	EFFORT OR CATCHABILITY LAMBDA GR TYPE 1
NONE	
COHORT	
0.5	
NONE	
kboot.out	
Y	PRINT LABELED RESIDS
Y	PRINT RESIDUALS

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Appendix B3.-Effort file.

1987	1	3026
1988	1	1666
1989	1	2421
1990	1	3225
1991	1	2748
1992	1	1721
1993	1	4329

Appendix B4.-Harvest file.

4	1987	1	1
5	1987	1	5.4066
6	1987	1	5.9663
7	1987	1	6.2176
8	1987	1	5.4066
9	1987	1	6.2176
10	1987	1	5.4066
11	1987	1	5.8121
12	1987	1	6.2176
13	1987	1	5.4066
14	1987	1	5.4066
15	1987	1	5.1190
16	1987	1	5.6298
4	1988	1	4.0902
5	1988	1	4.9375
6	1988	1	5.6307
7	1988	1	6.2105
8	1988	1	6.0362
9	1988	1	6.3928
10	1988	1	6.0827
11	1988	1	6.0362
12	1988	1	5.6997
13	1988	1	4.3779
14	1988	1	4.3779
15	1988	1	4.0902
16	1988	1	3.6848
4	1989	1	3.4584
5	1989	1	4.8447
6	1989	1	5.4043

-continued-

7	1989	1	6.5495
8	1989	1	6.4029
9	1989	1	6.0975
10	1989	1	6.3488
11	1989	1	6.3488
12	1989	1	5.8563
13	1989	1	5.6556
14	1989	1	5.2502
15	1989	1	4.5570
16	1989	1	3.4584
4	1990	1	0.0
5	1990	1	0.0
6	1990	1	0.0
7	1990	1	0.0
8	1990	1	0.0
9	1990	1	0.0
10	1990	1	0.0
11	1990	1	0.0
12	1990	1	0.0
13	1990	1	0.0
14	1990	1	0.0
15	1990	1	0.0
16	1990	1	0.0
4	1991	1	1
5	1991	1	4.0098
6	1991	1	5.4369
7	1991	1	5.8556
8	1991	1	5.7734
9	1991	1	5.6192

-continued-

10	1991	1	5.6838
11	1991	1	4.9906
12	1991	1	5.5139
13	1991	1	5.1084
14	1991	1	4.0098
15	1991	1	3.6043
16	1991	1	2.2180
4	1992	1	1.7314
5	1992	1	4.8669
6	1992	1	5.7204
7	1992	1	6.2087
8	1992	1	6.1741
9	1992	1	6.0219
10	1992	1	6.0489
11	1992	1	5.8903
12	1992	1	5.4926
13	1992	1	5.0272
14	1992	1	4.5040
15	1992	1	4.2964
16	1992	1	4.0340
4	1993	1	1
5	1993	1	1
6	1993	1	3.7906
7	1993	1	5.1769
8	1993	1	5.1769
9	1993	1	6.6810
10	1993	1	6.6238
11	1993	1	6.9686

-continued-

Appendix B4.-Page 4 of 4.

12	1993	1	6.3555
13	1993	1	6.3555
14	1993	1	5.5823
15	1993	1	5.7365
16	1993	1	6.0932

Appendix B5.-Weight file.

4	1987	1	1
5	1987	1	1
6	1987	1	1
7	1987	1	1
8	1987	1	1
9	1987	1	1
10	1987	1	1
11	1987	1	1
12	1987	1	1
13	1987	1	1
14	1987	1	1
15	1987	1	1
16	1987	1	1
4	1988	1	1
5	1988	1	1
6	1988	1	1
7	1988	1	1
8	1988	1	1
9	1988	1	1
10	1988	1	1
11	1988	1	1
12	1988	1	1
13	1988	1	1
14	1988	1	1
15	1988	1	1
16	1988	1	1
4	1989	1	1
5	1989	1	1
6	1989	1	1

7	1989	1	1
8	1989	1	1
9	1989	1	1
10	1989	1	1
11	1989	1	1
12	1989	1	1
13	1989	1	1
14	1989	1	1
15	1989	1	1
16	1989	1	1
4	1990	1	1
5	1990	1	1
6	1990	1	1
7	1990	1	1
8	1990	1	1
9	1990	1	1
10	1990	1	1
11	1990	1	1
12	1990	1	1
13	1990	1	1
14	1990	1	1
15	1990	1	1
16	1990	1	1
4	1991	1	1
5	1991	1	1
6	1991	1	1
7	1991	1	1
8	1991	1	1
9	1991	1	1

-continued-

10	1991	1	1
11	1991	1	1
12	1991	1	1
13	1991	1	1
14	1991	1	1
15	1991	1	1
16	1991	1	1
4	1992	1	1
5	1992	1	1
6	1992	1	1
7	1992	1	1
8	1992	1	1
9	1992	1	1
10	1992	1	1
11	1992	1	1
12	1992	1	1
13	1992	1	1
14	1992	1	1
15	1992	1	1
16	1992	1	1
4	1993	1	1
5	1993	1	1
6	1993	1	1
7	1993	1	1
8	1993	1	1
9	1993	1	1
10	1993	1	1

-continued-

11	1993	1	1
12	1993	1	1
13	1993	1	1
14	1993	1	1
15	1993	1	1
16	1993	1	1

APPENDIX C. TANANA RIVER BURBOT HARVEST, 1977-1994

Appendix C.-Tanana River burbot harvest 1977-1994.

River	Annual Harvest[a] (Number of Burbot)																	
	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Mainstem Tanana River																		
Lower Tanana R.[b]	0	0	0	0	0	0	0	0	0	0	40	218	130	236	113	93	11	180
Middle Tanana R.[b]	0	0	0	0	0	0	0	0	0	0	1,873	1,692	1,764	912	834	1,286	2,460	2,191
Upper Tanana R.[b]	0	0	0	0	0	0	0	0	0	0	409	509	411	641	654	338	685	823
Total Tanana R.[cd]	0	0	0	0	0	0	0	1,921	1,365	2,948	2,322	2,419	2,325	1,789	1,602	1,717	3,156	3,194
Lower Tanana River Tributaries																		
Chatanika R.	34	18	9	50	5	42	21	13	175	40	13	55	10	17	0	8	0	0
Nenana R.[d]	0	0	0	0	0	0	0	0	0	0	53	0	60	68	11	76	11	0
Minto Flats	37	72	45	9	32	21	0	39	105	32	132	0	20	0	56	0	0	208
Middle Tanana River Tributaries																		
Chena R.	642	389	807	1,127	1,317	1,457	1,055	1,233	2,065	889	149	386	1,322	304	225	1,032	1,135	737
Salcha R.	0	0	0	0	0	0	0	0	35	296	0	18	0	203	23	25	64	21
Piledriver Sl.[d]	0	0	0	0	0	0	0	84	0	0	79	55	100	456	203	195	568	73
Shaw Cr.[d]	0	0	0	0	0	0	0	415	175	120	607	0	170	354	45	161	161	93
Upper Tanana River Tributaries																		
DCR	0	0	0	29	0	0	0	13	0	0	26	0	0	0	0	0	0	0
Goodpaster R.[d]	0	0	0	0	0	0	0	221	350	88	13	109	120	0	0	17	86	0
Other Areas[e]	829	832	966	1,285	2,257	1,866	3,146	935	245	441	355	364	100	388	23	93	289	589
% Total											9.5	10.7	2.4	10.8	1.1	2.8	5.3	12.0
Total Lower River											238	273	220	321	180	177	22	388
% Total											6.3	8.0	5.2	9.0	8.2	5.3	0.4	7.9
Total Middle River											2,708	2,151	3,356	2,229	1,330	2,695	4,388	3,115
% Total											72.2	63.2	79.4	62.3	60.8	81.2	80.2	63.4
Total Upper River											448	618	531	641	654	355	771	823
% Total											11.9	18.1	12.6	17.9	30.0	10.7	14.1	16.7
Total All Areas	1,542	1,311	1,827	2,500	3,611	3,386	4,306	4,790	4,515	4,854	3,749	3,406	4,225	3,579	2,187	3,320	5,470	4,915

[a] Data from Alaska statewide harvest survey (Mills 1978-1995).

[b] River sections were not described as specific areas on the survey form until 1987.

[c] Includes harvests from upper, middle, lower, and unspecified sections.

[d] was not described as a specific area until 1984. Any harvest that may have occurred in this area would have been listed in the "Other this Areas" category.

[e] Was described as "Other Waters" on the survey form until 1984, and may have included harvests from lakes and ponds. Beginning in 1984, this category is listed as "Other Streams" on the survey form.